CHEMICAL FARMING

BY

CONRAD WILSON.

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These essays and discussions are prepared expressly for this Company, by the well-known writer, Mr. Conrad Wilson, and comprise, in an abridged form, most of the results of his numerous investigations during the last fifteen years.

Having been formerly a practical farmer, and most of his life a close observer, he is well qualified to discuss the problems of husbandry, not only in the light of theory, but as practical questions to be solved in the interest of working farmers, and in accordance with sound common sense.

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The following are some of the subjects included in this series:

1. Chemical Farming; Its possibilities, and its mistakes; illustrating the necessity and value of chemical elements, when the conditions are right, and the danger of them when the conditions are wrong, and including also an examination of the Stockbridge formulas.

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10. Agricultural Fairs; Needed reforms, and how to secure them.

Those who have seen the occasional articles of this writer in the leading agricultural journals will agree with our estimate of his fitness for the work here undertaken. If further evidence is needed, the following opinions, cited from a few well known authorities, will sufficiently indicate the capacity of the author, and the practical value of his investigations.

Mr. A. W. Cheever, editor of the *New England Farmer*, in a letter to Mr. WILSON, over a year ago, closed with the following tribute.

"As an editor desiring to make a useful paper, I feel honored by your proposition to write a series of articles for the *Farmer* and knowing that you have a heart in your work, I beg leave to thank you as well as I can."

Mr. E. S. Carman, editor of the *Rural New Yorker*, recently wrote to our author, (after quoting one of his papers in the *Rural*,)

"I have just read your address at the American Institute, 'How Agricultural Journals Benefit the Farmer.' It is so thoughtful, so benevolent, that I felt constrained to thank you for it, and I am sure many others interested in agriculture must share the same feeling."

The Elmira *Husbandman*, in citing from another journal an article by Mr. WILSON, on "Farmers Clubs," added the following spontaneous tribute:

"Mr. WILSON is a vigorous writer, and sets forth his ideas in such pleasant ways that readers are attracted. His articles are very widely copied in the agricultural press."

Dr. E. L. Sturtevant, in the *Scientific Farmer* of this month, records the following opinion :

"Our friend, CONRAD WILSON, has done more to elucidate the truth, and bring out the real facts of the fertilizer question than any of his contemporaries. He has done this by the evident fairness of his mind, as he seems always ready to be convinced of an erroneous opinion, although very tenacious in his views."

Mr. Geo. B. James, editor of the *American Cultivator*, in a letter of last August says :

"I have been much interested in your discussions. Such vigorous treatment is certain to provoke thought and investigation. You are doing good work and I am glad to see another independent thinker added to the list of agricultural writers,"

It is intended to publish the above series monthly, beginning with the discussion of *Chemical Farming* which will be issued during the present month.

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ABRAM REQUA, President.

CHEMICAL FARMING;

ITS POSSIBILITIES, AND ITS MISTAKES.

ILLUSTRATING THE NECESSITY AND VALUE OF CHEMICAL ELEMENTS,
WHEN RIGHTLY USED, AND THE DANGER OF THEM
WHEN THE CONDITIONS ARE WRONG;
INCLUDING ALSO AN EXAMINATION OF

THE STOCKBRIDGE FORMULAS.

BY

CONRAD WILSON.

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CHEMICAL FARMING.

INTRODUCTION.

In inviting the attention of American farmers to a subject so nearly related to their business as FERTILIZERS and MANURES, it is safe to assume that no apology is needed. On practical questions where all are concerned and great interests are at stake, the arena of discussion is open to all, and the humblest investigator may contribute something to the final result. If his own suggestions have but little intrinsic merit, they may still draw out valuable ideas from other sources, and thus the effort made is not in vain.

Plant food in agriculture is a theme so fruitful, and of such endless interest, that it can hardly be too much examined. A single mistake in the use of it, if committed by one man and carelessly copied by another is liable to be still further repeated and multiplied, until it is launched on a wide career of mischief leaving its trail through a whole community. But if a mere casual mistake is capable of such results, how much more serious is the consequence when error is deliberately (though unconciously) engrafted upon a system, and thus made perpetual.

In this view therefore it may be confidently assumed that great practical questions should be closely investigated. Agitation in such cases is always profitable, and often the source of ultimate truth.

To supply the soil with plant food of the right kind, in the true proportion, and in the best condition for immediate effect,

is to-day the great problem of our husbandry. Earnest farmers are everywhere discussing the question, and earnest thinkers in both hemispheres are endeavoring to solve it. Nor is it at all surprising that a general interest is felt on a subject so important. For the man who liberally feeds his growing crops is, at the same time, feeding his own household, and helping to feed the human race.

This broad subject, along with other farming topics of similar interest, I have occasionally discussed in some of the leading agricultural journals; and the more I have looked into these problems the more I am impressed with their magnitude and their difficulty, and the more I am convinced that they require much careful thought and a spirit of patience that can

"Learn to labor and to wait"

PROMINENT INVESTIGATORS.

Among those who have recently attracted attention to this subject, and have thus rendered important service to husbandry are Prof. Ville, Mr. Lawes and Prof. Stockbridge. Each of these eminent men has devoted much thought and study, as well as practical effort to demonstrate the value of chemical fertilizers, and though their views differ somewhat, as well as their practice, the general result is that plant-food has been lately more widely examined than ever before, and the necessity of using it, *under right conditians*, is beginning to be better understood.

Yet it will be found on examination that these earnest investigators have each made some mistakes which, though too important to be ignored, or tacitly accepted, do not necessarily affect the separate and independent value of their other sound conclusions. For the solid and lasting results they have achieved their fame is already secured. But while admitting their great ability, and scientific attainments, and conceding the full measure of their well earned renown, it would be neither wise nor just to overlook their mistakes, or to tolerate errors that are clearly damaging to the farming interest.

On the theory of Prof. Stockbridge, I have already briefly commented through the press, and I propose in these pages to examine it still further, in reference to some essential points not yet discussed. Whatever may be the faults of this system, it certainly has one aspect that deserves applause, and creates a presumption in its favor. It is sharply outlined, and so clearly stated that it cannot be mistaken. It claims much, but the claim is bravely made. Liberal promises, when accurately stated, are always attractive. For this reason the theory, if sound, is so much the more valuable ; but if unsound, so much the more dangerous.

It is not to be denied that in the system of Prof. Stockbridge the fundamental principle is sound, and that some of the conclusions are true and important. It is therefore unpleasant to

discover and still more so to criticise, even palpable errors, when engrafted on truths that are undoubted and eternal. Yet the world recognizes no test of merit but practical results. By this test every system must stand or fall. In questions of universal interest personal considerations disappear.

If chemical elements have been found more successful by other processes than by these formulas, and this fact can be clearly established, if the theory now on trial can itself be materially modified so as greatly to enhance its certainty and its profit, and if it can be further shown that the total difference at stake on this question is equivalent every year to millions of dollars, then why should criticism be silent; or why should investigation, when it has reached this conclusion, stop short, from mere lack of courage to utter the truth?

In the investigation of this subject one distinction is very essential. While I fully admit the great value of chemical *elements* to the farmer, it does not follow that chemical *formulas* are either valuable or safe. The elements of plant-food, as revealed in chemistry, are the creation of Infinite wisdom, and their efficiency is determined by natural laws. Formulas are the product of a finite mind, and may be valuable, or otherwise. That they are in certain cases well adapted and successful, and occasionally give striking results is not denied. But the net result of yield, cost and final profit that is claimed for them, on a general average, can only be safely accepted when definitely proved.

But if it shall be clearly shown that the system is not in harmony with natural laws, that the testimony of experience is thus far against it, and that the tendency of the formulas is to reduce the profit of crops, and ultimately to diminish the use of fertilizers, and the business of dealers, then every man who tills the soil, and every dealer in chemical elements will be able to judge where his true interest lies.

METHOD IN FERTILIZING.

In farming, as in every thing else, method implies thought, and is, therefore, one of the largest factors in successful results.

It deals with the facts of experience, and by arranging them in harmonious relations brings order out of confusion, and converts darkness into light. This truth holds good in every branch of agriculture, and is no less important in fertilizing the soil than in harvesting the crop. In all cases those who are guided by a plan are most successful, and the farmer who works by method gets larger results, and with more certainty than one who works at random.

Is it not then clearly expedient for farmers to examine the methods and systems in agriculture as the surest way to understand the subjects to which they relate; and will not those who are seeking further light in regard to fertilizers find it their interest to carefully investigate prevailing theories?

The present drift and tendency of husbandry are evidently in the direction of chemical farming, and no man can fail to get light on that question, as well as on the whole subject of plant food, who thoroughly examines the Stockbridge theory. The more we discuss the merits of nitrogen, potash and phosphoric acid, the sooner we shall reach the ultimate truth in regard to the other chemical elements, also as well as for barnyard manure. Already the debate on this question has drawn out from Professor Stockbridge a fuller statement of his views, (as will shortly appear,) and the time is probably not distant when every form of plant-food will find its appropriate place in the economy of the farm.

A BRIEF REVIEW OF FORMER COMMENTS.

Having formerly discussed some parts of this system in various journals, I will here briefly condense the points already made in the argument which will simplify the discussion, and make shorter work afterward in dealing with the main questions on which the theory chiefly rests, and which have not yet been examined.

Among the numerous trials that have been made with a view of testing this theory, probably the most important and conclusive are those conducted by the Professor himself, and by Sturtevant Brothers, at Waushakum Farm. Certainly no man can be

presumed more competent to test these formulas than the eminent scientist and practical farmer whose genius created them; while it is equally certain, as far as relates to Dr. Sturtevant, that very few men, in this country or any other, are better qualified than he to make thorough and successful experiments in farming. It is therefore clear that no examples could be cited that would be more likely to illuminate this question than the trials made by these eminent men.

On the first, and most noted experiment of Sturtevant Brothers, I made some comments at the time in the *Country Gentleman* and afterwards more at length in the *Practical Farmer*. It is not now necessary, for the purpose here in view, to present the analysis then made of this elaborate and comprehensive performance. That the trial, though conducted on an extended scale, and with an evident purpose to make it thorough and complete, did not confirm in any particular the soundness of the theory, was demonstrated clearly and beyond any question. This experiment was, of course, only a single fact and though bearing on a grave problem, no more weight is claimed for it, as an argument, than it fairly deserves.

But as an experiment it was every way suggestive, and fruitful of results; and though it did not yield precisely the fruit that was expected, it clearly demonstrated a number of possibilities that deserve attention. Though it did not in any way indicate the soundness of the Amherst formulas, nor show that three elements of plant food are all the farmer needs to supply for a maximum yied of corn, it stands on record to prove the possibility of growing corn in New England with barnyard manure, at the rate of one hundred bushels per acre, and at a cost of less than thirty cents a bushel.

Yet this fact, important as it is, does not measure the full value of the experiment. Even in its mistakes this trial is radiant with instruction. It shows that in the experiments of a man of genius the very failings may sometimes be converted into success by discovering in them unsuspected results of great value.

But without dwelling longer on this head, let me here refer to

AN IMPORTANT DISTINCTION,

in regard to *cost of production* which this theory leaves out of view.

This point is made clear in the following passage from a paper of mine, read at the American Institute Farmers' Club, and subsequently reproduced in various journals:

"The mere question of increased yield from fertilizers, which Prof. Stockbridge seems to consider the essential thing, is not so regarded by practical farmers. It is, doubtless, important, but by no means conclusive. To add fifty bushels to a given yield may be profitable or not, according to its cost. But the real question is, how does the extra product affect the cost per bushel for the *whole crop?*

"The true way to test the value of the theory is to add the extra yield produced by fertilizers to the normal yield, (or yield without manure,) and then calculate the cost per bushel for the total crop. If then we assume the average yield of corn, without manure, for New England, at twenty-five bushels per acre, there still remains the charge for plant food drawn from the soil by the normal crop, to be added to the cost of the fertilizers applied.

"Now if we take the cost of plant food, including both these factors, and add the other expenses according to the figures of Dr. Sturtevant in his "*Chemical Corn-growing*," it will be found that the best result that can fairly be claimed for the system, on a general average, would bring the yield and cost for corn to seventy-five bushels per acre, at over sixty cents per bushel."

And even this result is only possible, by taking for granted, 1st. That the average yield *without manure* is not less than twenty-five bushels per acre; and, 2d. That the corn formula costing $25 will give an increase of fifty bushels, both of which are very uncertain, and the latter extremely improbable.

Thus, in the best view of the case, the cost of corn by this method would be sixty cents per bushel. and very often more. But the Doctor has already given us, with barnyard manure, one hundred bushels per acre at twenty-nine cents per bushel, and other brilliant farmers, in other localities, have often given a still larger yield, and still lower cost.

EXPERIMENT OF PROF. STOCKBRIDGE.

In the following passage from a former paper in the *New England Farmer*, I have examined an important experiment of the Professor which had previously been submitted by him as a trial crop and was regarded as a confirmation of his theory. It will be seen by the figures, given below, that the result is very far from encouraging. The passage cited goes on to say:

"Experience has taught that both these sources of plant food, (fertilizers and manures) are of priceless value to the farmer, and that nothing is gained by either in attempting to make one of them independent of the other.

"But leaving this point for future consideration, my present purpose is to show that the experiment of Prof. Stockbridge, as cited by himself, in which he applied the material for fifty bushels of corn and obtained ninety-four bushels, does not by any means support the conclusion so strongly stated, 'that this method of feeding plants is the cheapest of all methods of producing them ; the cheapest in the world ; cheaper than barnyard manure ; cheaper than anything known.' Let it be understood that I am not here denying the validity of this claim. It may be well founded, or it may not. That will appear hereafter. I simply remark that the experiment cited does not prove the point claimed.

"Let us glance at some of the facts and figures. The Professor estimates the value of his crop at $102.52, including the stover. The plant food applied for fifty bushels is charged at forty-one cents per bushel, making $20.50. He then adds, 'I got ninty-four bushels of corn for $20.50, and I have got $82.02 on my crop to pay for my labor, my taxes, and my interest.' Now, if we assume the cost of these items to be at the same rate as reported by Dr. Sturtevant in his experiment of last year, then the account of the Professor's crop will stand as follows:

Seed and labor, including harvesting and husking	$30 62
Fertilizers for fifty bushels	20 50
Plant food for forty-four bushels, to be charged as exhaustion of soil	18 04
Interest and taxes, as formerly estimated by Dr. S	10 00
	$79 16

Deducting this cost from the value of the crop, as given by the Professor ($102.52,) we have $23.36 as a profit on one acre of ninety-four bushels."

But here it is necessary to make an important correction. The cost of chemical elements for corn, by this theory, (as I have elsewhere shown,) is over fifty cents per bushel, and the dealers price list makes it fifty cents. Consequently the charge for fertilizers above should be,

For fifty bushels	$25 00
For forty-four bushels	22 00
	$47 00

This makes a difference of about $9.00 per acre in the cost of production; which brings the profit per acre to *less than* $15.00.

This falls far below the results obtained by Dr. Sturtevant in his experiment of two years ago, as will be seen by comparing it with his very elaborate and carefully considered paper on "Chemical Corn Growing," a copy of which I have had the pleasure of receiving from him.

But there is another defect in this experiment which, though not alluded to in my former examination of it, is too important to be overlooked. The Professor has reported forty-four bushels per acre as the normal yield of his land, though the experiment does not embrace any provision for testing this point. As no facts are given to show what the normal yield really was, how are we to know that this is correct? The mere fact that fertilizers were applied for fifty bushels does not at all prove that the increase actually *was* fifty bushels, or that the normal yield was just forty-four bushels. To assume this would, of course, be very convenient, but it is simply taking for granted the point to be proved, and is hardly the kind of reasoning that plain farmers have a right to expect from scientific men. It is entirely possible that either the natural capacity of the soil, or the fertility inherited from previous manuring, or both of these causes combined may have been sufficient for a yield of even sixty-four bushels per acre. In that case the increase from chemicals would be but thirty bushels. But if, when chemical elements are applied according to the formula for a given amount, this is alone sufficient to prove that they produce that amount, then there is clearly no need of the experiment, which is simply an incumbrance to the argument rather than a demonstration.

A VINDICATION OF MANURE.

The following article, which appeared in several agricultural journals, had the effect, as I was gratified to find, of drawing out from the Professor an elaborate reply, and also a hope, courteously expressed in a letter to me, that it might lead to further friendly discussion. It is therefore here submitted, together with the discussion arising out of it.

"There is nothing more discouraging to those engaged in husbandry than errors committed by scientific men writing in the interest of agriculture. The prosperity of farmers so largely depends on their readiness to accept the conclusions of science that anything tending to weaken their confidence in its professors rises to the importance of a national misfortune.

In this view the position taken by Prof. Ville and Prof. Stockbridge, in regard to barnyard manure, would seem to be of questionable policy, even if tenable and sound. But let us glance briefly at the doctrine of these prominent writers, and see whether their conclusions are really justified by the facts.

"It has been claimed," says Prof. Ville, "that the meadow is the foundation of all good agriculture, because with the meadow we have cattle, and with cattle manure. These axioms are now veritable heresy. I hope to show you that agriculture to be remunerative must be founded on artificial manures." Again: "The intervention of animals being a necessity of circumstances, manure is produced, and we are compelled to take notice of it."

In like manner, Prof. Stockbridge is equally positive in claiming that chemical fertilizers have emancipated husbandry from the need of animal dung. In reporting his own experimental corn crop, he describes his method of feeding plants as "the cheapest of all methods of producing them; and *cheaper than barnyard manure.*" Like Prof. Ville, he seems to regard barnyard manure as a sort of necessary evil, a *waste product of the farm*, to be utilized simply because it is there.

Let us now see if there are not some facts of experience, some conclusions of practical men, as well as scientific authority that may tend to correct this erroneous estimate of barnyard manure.

EXPERIMENT OF DR. DANA.

From the elaborate experiment made by Dr. Samuel L. Dana it appears that an average cow, kept on a daily ration of twenty four pounds of hay, and twelve and one-half pounds of potatoes, will yield, in addition to her liquid evacuations, over 31,000 lbs. of dung per year, containing 189 lbs. of ammonia, which, with other included elements amount in chemical valuation to over $40. By the same authority it also appears that the liquid manure amounts to over 7,000 lbs. a year, and surpasses the solid dung in value in the ratio of two to one. This makes the total value of the manure more than equal to the entire cost of feeding. He further states that "100 lbs. of cattle urine afford about eight pounds of the most powerful salts ever used by farmers."

ESTIMATE OF PROF. JOHNSON.

It is estimated by Prof. Johnson that a ton of clover contains potash, phosphoric acid and nitrogen sufficient to make it worth $17.57 for manure, while a ton of bran or of peas is worth, by the same standard, over $22. And some other feeds have a still higher manurial value. In the above experiment of Dr. Dana the daily ration of hay was equivalent to four and one-fourth tons a year. Now if this ration had been clover instead of hay, the manurial value per year would have been over $72, according to the authority of Prof. Johnson. These conclusions, resulting as they do from both] practical and chemical investigation, are further confirmed by the experience of successful farmers.

JOSIAH QUINCY, JR.

This gentleman has found that a good cow, when kept on the soiling system, yields three and one-half cords of solid dung per annum, which, by the addition of muck, may be more than doubled, both in quantity and value, and that the liquid manure when absorbed with muck is worth still more than the solid, making an aggregate of more than fourteen cords, worth from $5 to $8 a cord. And further it appears that the total manure from each cow, when thus treated, is equivalent, on a yearly average, to the value of the milk.

JOSEPH HARRIS,

who probably knows as much about manure and more about pigs than most farmers, has estimated that he got forty-one and three-fourth cents worth of manure from pigs that were fed at a cost of thirty-seven and one-half cents per week, thus showing that the value of the manure covered the whole cost of feeding, and left a net margin of profit besides.

Again the memorable yield of Indian corn obtained by

J. W. DICKEY,

of Pennsylvania, which amounted to 169 bushels per acre, was the product of a soil previously pastured by sheep, and the success of the yield was largely attributed by Dr. Dickey to the fertilizing value of sheep manure.

In another memorable instance the prodigious yield of corn, amounting to 200 bushels per acre, which was obtained by

DR. J. W. PARKER,

of South Carolina, was mainly the result of two liberal applications of barn-yard dung, one of which was spread and plowed in the fall, and the other was applied in like manner in the following spring.

Another instance, elsewhere stated, is still more directly to the point, as the experiment was made for the very purpose of testing the superiority of chemicals over animal dung, while the result was entirely in favor of the dung. This elaborate experiment of

DR. E. L. STURTEVANT

is full of instruction, and deserves the attention it has attracted.

The manurial value of corn, fed to pigs, according to Mr. Harris, is a little over half a cent a pound for the grain fed, which is equivalent to thirty cents a bushel. This estimate presents a still more striking view of the Doctor's experiment. It shows that his hundred bushels of corn, produced by good manure from a single acre, at a cost of twenty-nine cents, was worth more in the manurial value alone than all the cost of rais-

ing it. Yet we are told by Prof. Stockbridge that barn-yard dung is but a waste product of the farm. Now, the question I wish to ask here is this: How much does it diminish the value of the results here cited, to say that the barn-yard dung from which they were produced is a *waste product* of the farm? It is easy to perceive that what are called waste products are only such while we permit them to be wasted. Just as soon as we begin to utilize them their character is changed, and they are waste products no longer. If animal dung is really a waste product, how amazing is the delusion of Mr. Harris and thousands of other farmers who are continually purchasing malt combs, bran and oil-cake, not only for their feeding value, but also because they make rich manure."

As soon as the above communication had appeared in print Prof. Stockbridge sent in his very able reply, which was promptly published in the same journal, accompanied with my rejoinder. and afterwards reproduced in the *Massachusetts Plowman*, from which, however, my rejoinder was excluded, *contrary to agreement.*

Yet this arbitrary proceeding has proved to be of little moment, as it has not by any means arrested the progress of truth, and free discussion. Having enlisted in this debate under a deep conviction of the importance of the subject to every farmer in the country, I propose to keep my ground, and finish the work. If the editor of the *Plowman* sees fit to suppress entirely the argument of one side, that is a matter between himself and his readers. If they can afford it, no one else need object. I shall show before this discussion is ended that the theory of exact formulas is both unsound and unsafe; that it has not only never been proved, but never can be, for the simple reason that it is contradictory to natural laws, and that in nearly all the cases reported as satisfactory, the success is apparent rather than real, as a more thorough examination will show. When these facts are made to appear, it will be of little consequence whether the *Plowman* shall see fit to admit them by a prudent silence, or boldly come forward to refute them.

But meantime the first thing in order is to submit here my answer to the Professor in which it will be seen that his positions are fairly refuted.

The following is my

REJOINDER TO THE PROFESSOR'S ARGUMENT.

In opening his argument to meet my position, Prof. Stockbridge appears to be under the impression that I have not done full justice to his opinion relating to barnyard manure, and I am now gratified to learn that he has a better opinion of that material than has generally been supposed.

Yet the fact still remains evident that some of his views on this subject, as well as the similiar views of Prof. Ville, are not entirely sound, and tend to depreciate the value of animal dung in the estimation of farmers. To most farmers a *valuable* product and a *waste* product are phrases which convey very different ideas and should not be applied to the same thing.

But it can hardly be worth while to dwell on this point. Phraseology is always more or less a matter of taste, in which every man has a right to suit himself. And yet it is true that a single phrase sometimes becomes the means of propagating error.

But Prof. Stockbridge has made an issue on yard manure that is more clear and unmistakable than this. When he says it is not necessary nor even desirable to keep cattle for the express purpose of making manure to renovate our fields with, he opposes the convictions and experience of the soundest practical farmers, many of whom have redeemed their land from sterility, by this means alone, when other means have failed.

It will be found that the farming lands of this country, as a rule, retain their fertility the longest, and recover it the most readily and surely in those cases where the stock of the farm is sufficient to consume its products. In fact experience has proved that it often pays the farmer to go beyond this limit, and to increase his stock, even beyond the feeding capacity of his acres. This is the opinion of nearly all of our thriftiest farmers,

and it is also one of the secrets of successful farming in England, where the average yield per acre is nearly double the product of our own country, and where the farmers understand the importance of manure and are shrewd enough to increase its value by using American cotton seed and oil cake, which our farmers will some day be wise enough to use at home.

But the Professor says that I have attempted to prove "that animal excrement has a greater value than the crops consumed to produce it." I have not even claimed, much less have I attempted to prove it. I cited certain figures from an experiment of Dr. Dana, as making the value of the manure more than equal to the cost of the feed. But the difference between cost and value, from the standpoint of the farmer is very material.

CHEMICAL FIGURES.

In applying to any given case the chemical value of manure, as derived from analysis, I do not necessarily affirm the soundness or accuracy of that value. How far it *is* a test, is a matter that still remains to be considered. Most of the cases I have cited are taken from the experience of farmers, and are independent of chemical figures. But in *all* the cases referred to, the facts alone are sufficient for my purpose. Yet so far as the testimony of chemistry is of value to the farmer, my position is made stronger by it.

I have nowhere said, as he intimates, that Dana's cow consumed food to the value of $92, and produced manure worth $120. These are simply the figures of Prof. Stockbridge, and not mine, nor Dr. Dana's, as will more fully appear shortly.

Again, I have nowhere affirmed the value of the food consumed by Harris' pig, nor the value of the excreta it produced. I simply gave his statement of the *cost* of the feed, and his estimate of the value of the manure based on chemical figures. These figures ought certainly to shed some light on the subject, and they undoubtedly do. It is something for the farmer to know what proportion of nitrogen, potash, lime, etc., are contained in a ton of hay, corn meal or bran. If the science that reveals this does not

inform him also how much of these elements are at once available as manure, nor in *what way* they may be made available, this only shows that chemical science has still an important work to do. Meanwhile the farmer, while waiting for this illumination, must resort to other sources of knowledge. How to make plant food available is the information he needs and is bound to have, either by the aid of chemistry or by practical experiments of his own.

We now come to the next stage of the Professor's argument, in which he presents his case vigorously, and makes his points with admirable skill and inimitable humor.

"Did these animals," he inquires, "take out of their food any of its elements to make milk, bone or muscle! If not, they were peculiar and profitable animals, if they were not themselves consumed; but especially if the cow gave a fine quantity of milk, and the pig increased in weight as fast as Harris's pigs generally do. If this is really true, if there is no mistake about it, it opens

A NEW BRANCH OF INDUSTRY

for the farmer, and crops are the waste or raw material, and manure the realand valuable product. The problem of perpetual motion is solved, and 'how to make something out of nothing.'"

In regard to the first inquiry above, it is enough to say at present that the chemical elements absorbed from the food of animals to maintain their functions amount, on a general average, to a loss of about five per cent. in the value of the manure. This is the estimate of good judges, including, among others, Mr. Harris, who has examined the subject closely. But to remove all doubt on this point, let us put the loss at ten per cent. How far this loss affects the question in hand will be made sufficiently evident in the course of this discussion.

But the Professor intimates that the examples I have cited tend to "open a new branch of industry," in which, "crops are the waste or raw material and manure the real and valuable product."

This idea, though intended as irony, is not by any means so absurd as he seems to think. As a practical farmer, Prof. Stockbridge can hardly fail to know that crops, in certain cases are used to-day, and have been for a long time, as raw material for creating manure, and often with decided advantage. Whenever practical farmers plow into the soil a crop of buckwheat or clover, *expressly* to feed the following crop, or whenever they apply wheat bran, corn meal, cotton seed, &c., directly as manure, which is sometimes tried and found to pay, then they are literally using one crop as the raw material for feeding an other, and we now learn for the first time, that in doing this, they are revealing the mystery of perpetual motion, and teaching mankind how to make something out of nothing.

But this subject is too fruitful to be now exhausted, and must be left for further investigation, in another treatise, when I expect to show that feeding animals for the *express* purpose of making manure is capable of being made much more profitable than many of us suppose, and that it will probably become a distinct feature, if not a separate industry in the farming of the future. It will also then be shown that the progress of husbandry and the profit of farming are hereafter to depend in large measure on improving the quality and increasing the amount of barnyard manure (in connection with chemical elements,) and that these results are only to be developed through a *series of experiments* entirely new, and different from anything in the experience of the past.*

But Prof. Stockbridge seems surprised to learn that the dung produced by Dana's cow largely exceeded the weight of her food, and the difference, he thinks, must be due to the water she drank.

Skillfully as this fact is presented by the Professor, and formidable as he makes it appear, yet a moment's reflection dispels the illusion, and we cease to be astonished.

The simple fact that the water which animals drink adds to the amount of their dung, and yet does not increase its fertilizing

* This entire subject will be fully discussed in my forthcoming treatise on "Barnyard Manure."

value, has long been familiar to observing farmers, and should hardly appear surprising to a man of science. But conceding for the sake of courtesy that this is a wonderful fact, what does it after all amount to? It is enough for me to show that the food consumed by the cow in this case will account for a sufficient amount of valuable elements in the dung for my purpose, and it matters very little whether different chemists, in estimating these elements, differ from each other or not. After allowing for all disagreement, I find the nett result of their testimony confirming my position. If Dr. Dana has rated the value of cow dung a trifle too high, or if Prof. Stockbridge has rated it much too low (as will be seen directly), in either case the real question is not affected.

My position is that animal dung has a greater value than the theory of either Ville or Stockbridge concedes to it. To show this, I have cited various examples in practical farming that seem clear and convincing. I have also cited the main facts and figures of an experiment by Dr. Dana. Yet I do not claim that he is infallible, although his figures are confirmed by other authorities. If he finds in cow dung the amount of elements which he affirms, or even any where near the amount, then I am warranted in accepting his figures as chemical testimony in favor of animal manure, even though the science of chemistry is still at work on an unfinished problem, and cannot yet tell the farmer all he needs to know.

A REMARKABLE CASE OF AMMONIA.

"But again," says the Professor, "Dana states that the 30,000 pounds of solid dung contained 189 pounds of ammonia. That is a remarkable statement. But the food she ate did not contain that quantity of ammonia before she substracted anything from it. The 4.38 tons of hay and 76.08 bushels of potatoes contained but 128,173 lbs. of nitrogen, equal to 149,613 of ammonia, and this is all it could have, if her system absorbed none of it, and it all went into her solid dung."

Now, on comparing the above figures of Prof. Stockbridge with other authorities, I find the amount of food consumed by

the cow during the year was sufficient to account for an amount of ammonia not only much greater than the Professor makes it, but even quite beyond the amount (189 lbs.) mentioned by Dr. Dana.

According to Prof. J. F. W. Johnston, the nitrogen in a ton of hay amounts to 30 lbs., according to Lawes and Gilbert to 33.6 lbs.; and these estimates are confirmed by Prof. Stockbridge himself, who, in his formula for one ton of hay calls for 36 lbs. of nitrogen. If then we take the estimate of Lawes and Gilbert, the hay consumed by the cow in one year (8,760 pounds) contained 147 lbs. of nitrogen, equal to 179 lbs. of ammonia.

The nitrogen in potatoes, according to Prof. Johnson is 1.5 per cent., which on the yearly consumption (4,562 lbs.) would be 68½ lbs., equal to ammonia, 83½ pounds.

This makes the total ammonia in the food of the cow for one year equal to 262½ lbs. If from this we deduct 10 per cent., which is double the proportion usually allowed for the nutriment taken out of the food by the animal system, it leaves about 236 lbs. Yet Prof. Stockbridge informs us that the total ammonia in her food for one year is only a little over 149 lbs., and this, he adds, "is all it could have if her system absorbed none of it, and it all went into her solid dung."

"But more remarkable yet," says the Professor, "this milch cow which discharged in her solid dung more nitrogen than was contained in all her food in its original condition, at the same time voided 7,000 pounds of urine, which in consequence of the fertilizing elements it derived from her food was worth two to one of the solid. With these facts in mind, note now the great money value of the excrements of the cow. The solid dung which contained more than all the elements originally in her food, were worth, it is stated, $40, the elements in the urine, which were worth two to one, $80; the whole worth, of course, $120. Now, this cannot be true."

Most certainly it is not true. But, as I have already stated, these are the Professor's figures, and nobody else is reponsible

for them. When I cited Dana's estimate of the urine at 7,000 pounds a year, and as surpassing the solid dung in value in the ratio of two to one, the only rational meaning of the statement is that 7,000 pounds of the liquid manure are worth *twice* as much as 7,000 pounds of solid dung. This is so clear that it ought not to need explanation. But the total solid dung is rated at $40, which gives $9.33 as the value of 7,000 pounds. Now, if we double this sum for the urine (making its value two to one of the solid), we have $18.66. This makes the entire value of the manure for one year $58.66, which is less than half the amount curiously cyphered out by the Professor, who has made the ratio of values more than four to one.

To shed further light on this subject, I commend Prof. Stockbridge to a statement in the *Scientific Farmer* for January, 1877, from which it appears that the nitrogen and potash in the urine of a cow, as deduced from experiments by Boussingalt, and based on the theoretical valuation of Prof. Goessman, has a value of over $34 a year, and the *Farmer* adds that Boussingalt places the value at $50.

This estimate of $34 for the nitrogen and potash of the urine, the *Scientific Farmer* considers a safe estimate, and the editor of the New England *Farmer* concludes from these figures that the total yearly value of the manure of an average cow cannot be less than $62.90, without including phosphoric acid.

EXPERIMENT OF MR. LAWES.

Professor Stockbridge assures us that the real value of animal dung has been exhaustively examined in the experiments of Lawes and Gilbert. If this is true, if these experiments really prove what he claims, then the Professor has made a point. But let us first see how the case actually stands.

It is not denied that in the barley experiment of Mr. Lawes the effect of ammonia salts was decidedly good, and the trial was probably a fair test of the efficiency of this fertilizer for the soil and crop to which it was applied. Yet it is equally clear that this series of trials was not by any means a true test for animal dung, nor at all conclusive as to its value.

An examination of these experiments would necessarily include some topics not pertaining to the main question now in hand, yet I must briefly refer to some points that seem to have been left comparatively out of view:

1. And first let me say, there appears to be a mistake or oversight in regard to the highest yield of barley from barn-yard manure. Mr. Harris has several times cited in the *Agriculturist* the leading facts relating to these barley experiments. In one of these statesments he says, referring to the experiment above described, the average yield for 19 crops grown on the same land each year was 48 bushels per acre on both plots. But in another place, he says the plot that was manured every year with yard manure averaged 54½ bushels per acre and over 1½ tons of straw. Mr. Harris can doubtless shed some further light on this point.

2. But again, is it correct to say that 41 lbs. of nitrogen in ammoniated salts produced as much effect as 200 lbs. of nitrogen in the manure? If this is so, and if the yield of barley depended entirely upon the single element of nitrogen, why was it necessary, on the fertilized plot, to supplement the nitrogen with mineral salts, even in the proportion of more than 7 to 1. If, on the other hand, these elements were useful, or essential, if they really added to the yield, why give the exclusive credit to the ammonia? And further, if these salts were found profitable in this case, why not make them equally profitable, by applying them also as a supplement to the manure? If Mr. Lawes, instead of applying the manure to excess, had used one-half or two-thirds of the quantity, and replaced the part omitted with mineral salts *of the right kind and in the right proportion*, it is nearly certain the result would have been more profitable, but in any event the experiment would have been far more instructive.

3. Again, it appears from the product of the unmanured plot that the natural yield of the land sown to barley was 23 bushels per acre. This indicated that the natural supply of nitrogen in the soil was about 28 lbs. per acre. Now the manured crop, with its yield of 48 bushels, would take from the soil, according to Harris, 56 lbs. of nitrogen per acre. (Lawes makes it more than this, Wolff and others make it less.) But as the natural supply of nitrogen in the soil was equal to 28 lbs. per acre, the crop would only take out 28 lbs. more; making the total abstracted in 19 years equal to 532 lbs., while the nitrogen added to the soil during the same time by manure, as estimated by Lawes and Har-

ris, was 3,800 lbs. This would leave a balance of accumulated nitrogen in the soil at the end of 19 years (if none had leached out), equal to 3,268 lbs., instead of 1,736 lbs., as given by Harris.

If, then, we assume the loss of this nitrogen by drainage to be even 20 per cent, there would still remain in the soil at the end of the experiment over 2,600 pounds more than it contained at the beginning. From this it appears that though the application of manure in the first year of the experiment was but 14 tons, yet by annual accumulation it was equivalent at the twentieth year to 14 tons, plus 2,600 pounds of nitrogen.

Does not this clearly show that too much manure was applied? We have found that half the nitrogen needed for a yield of 48 bushels per acre was already in the soil waiting for the crops, and only 28 pounds more per year were needed. If to secure this Mr. Lawes found it necessary to apply 28,000 pounds of barnyard dung each year, in addition to the accumulation of former years, it simply proves that something was wrong either in the manure or in the method, or possibly in both, and it should hardly require more than three or four years to make the discovery.

After investigating and testing yard manure in this series of trials for nineteen years, and in some other cases for nearly twice that period, if he still finds, as the net result of so much time and effort and outlay, that nothing less than 200 pounds of nitrogen in manure will insure 28 pounds of available nitrogen for the crop (and that this 200 pounds will require 28,000 pounds of manure to produce it.) I have only to say that there are very many farmers in this country, and doubtless in England also, whose experience practically contradicts this conclusion, and who find little or no difficulty in getting larger yields and lower cost than the above ratios imply.

There is undoubtedly a right mode of treatment for animal dung that will put nitrogen into it, and another mode of treatment that will keep it there till it is wanted, and there is still another method that will bring the nitrogen out of the manure when the growing crop requires it. There is also a mode of experiment that will reveal to the farmer the right treatment for this manure, and that will produce a material more rich in nitrogen than 200 lbs. to 14 tons, and in which the nitrogen is more available for the crop than is implied by the ratio of 1 lb. in 1,000.

But the system of experiments that will give such results as these is not limited to one unvarying standard of quantity without increase or diminution, and without any addition of other elements to relieve the monotony of 14 tons a year for a whole generation.

It is also equally certain that the results I have described are not to be had from a quality of manure in which the actual dung is 1-5 of the whole, while the remaining 4-5 are only straw. Yet this I infer from a recent lecture of Mr. Lawes is the character of the manure used in his experiments.

But I have also seen it stated that it is the practice of Mr. Lawes to apply the liquid portion of his manure mostly to his grass land. If this is true, and if the barn yard dung used in his experiments on cereal crops is simply the solid portion of the manure apart from the liquid; this fact will still further diminish the value of his experiments with animal dung.

Now if, in the case of these barley crops, the quality of the manure is such that the crop can only get 1 pound of available nitrogen from 1,000 pounds of the dung, this clearly shows the necessity, not only of improving the manure, but of varying and multiplying the forms of the experiment. Unless this is done, the experiment ceases to be instructive, and cannot be accepted as a fair test either of the value or the possibilities of animal dung.

HOW TO GET AMMONIA.

Prof. Stockbridge seems to be under the impression that Harris has a lively faith in chemical figures when applied to chemical elements, but very little respect for them when they appear to give value to animal dung.

On this point let us take the testimony of Mr. Harris himself. After citing Professor Johnson's figures for the manurial value of malt dust, bran and meal, he says:

"To a farmer who buys as much bran and other feed for sheep and and pigs as I do, there must be encouragement in these figures," and though he considers them too high, he adds, "we certainly ought to be able to make considerable profit from feeding stock, and making manure on our farms." This is precisely the thing that the Professor, in one of his addresses, has assured us it is not necessary, nor *even de-*

sirable to do. Yet Mr. Harris, in his experience, finds it *profitable* to do so, and also finds *encouragement* in doing so, from the chemical figures of Prof. Johnson.

In another place he tells us he enriches his land by feeding clover to animals, and returning the manure to the soil, rather than plowing it under, and finds that this plan, while it produces as much grain "adds greatly to the fertility of the land, and gives an increased production of beef, mutton, wool, butter, cheese and pork."

Again, to a correspondent, who inquires for the best way to get ammonia, he replies:

"How to get ammonia at the cheapest rate, is the great question of scientific agriculture. Keeping sheep and raising clover, rape, mustard, peas and other highly nitrogenous crops to feed them on, and buying some bran, oil cake, &c., in addition, is as good a plan as I can suggest."

In another passage he advises to "keep sheep, and buy bran enough to give each sheep from one to two pounds per day in addition to clover and straw." He then adds:

"There is no cheaper way of getting manure."

In still another passage Mr. Harris refers to the experience of Lawes and Gilbert, in favor of animal manure. After citing a remarkable yield of clover from sulphate of potash, he gives an account of another clover crop, grown on a garden soil, when no fertilizers were used, but only yard manure from time immemorial, and the result was over nine tons per acre.

THE MONEY VALUE OF COW MANURE.

Prof. Stockbridge claims that in the case of Dana's cow, the money value of the manure, according to Lawes' experiment, was only $24 a year. Let us now see if this is so.

When we come to speak of the real value of manure, we pass at once from the laboratory to the field. It is no longer a question of analysis, or of the market price of ammonia, but simply of the actual money value that comes back to the farmer for the manure used, including also the increased fertility imparted to his land. In this view of the question, how does the case stand? Mr. Lawes applied 14 tons of yard manure and got an increase of barley equal to 25 bushels of grain, and 1,580 pounds of strow. He also added to this land an amount of fertility represented by the unused manure. If these 25 bushels of barley

together with the straw, were worth $30, and if half the manure is charged to future crops, then the $30 will show the agricultural value of seven tons of manure, which would be $4.28 per ton.

Now, it is not material whether these figures for barley are exact or not. They are probably too low. But they show sufficiently the direction and force of the argument.

If Mr. Lawes finds in seven tons of barnyard manure (consisting of four-fifths litter and one-fifth dung) a real value of $30, how far does this go to settle the value of a year's product of manure in the case of Dana's cow, wherein the material was pure dung, and the amount was 15 tons of fresh manure and 7,000 pounds of urine? As I have already said, I do not consider the barley experiments a true test of the value of animal dung. But in this case, if they prove anything, they prove that the manurial product of Dana's cow for a year was worth not $24, but nearly three times that amount. They would make it at least equal to the estimate of the *New England Farmer*, which was based on the figures of Boussingalt and Goessman.

I cannot, therefore, agree with the professor that the real value of animal dung has been *exhaustively* investigated in the barley experiments. If this is so, it certainly does not appear in the cases referred to by the professor, nor in any of the citations of Mr. Harris.

Did Mr. Lawes, at any stage of these barley experiments, try the effect of a smaller quantity of manure gradually increased through successive years? Or what would have been still better, did he, without discontinuing the 14 tons, introduce other plots, with less quantities of dung, for the purpose of comparison? If he did, and no results are given, then the facts referred to by Prof. Stockbridge, and Mr. Harris, are only a part of the experiment. On the other hand, if Mr. Lawes has not thus extended his investigation, so as to cover the whole ground of this inquiry, how does he know that 14 tons of yard manure was the smallest quantity that would give 48 bushels of barley per acre?

Is it not clear that if more conditions had been added to this experiment, it would have been much more instructive as to the actual value of manure? It was, doubtless, a grand experiment for other purposes, and it certainly shed much new light on various important questions.

I am far from disparaging the vast results that *were* obtained in this, as in all the other investigations of the great English farmer. But I ob-

ject to claiming results that were not obtained. I find no fault with the 14 tons of manure, considered as *one of the factors* of this trial. Nor do I at all object to the long period of time through which they were continued. Time is certainly a great element in experiments, and for some purposes, is even indispensable.

But a long period is not equally indispensable in all cases. The point I contend for is simply that if certain other conditions requiring less manure and less time had been added to these trials, they would have given another series of results, that are now entirely lacking, and which would have gone far to settle the actual value of barn yard manure.

If, for example, the trial had included other plots with eight, ten and twelve tons respectively of yard dung, and still another with sixteen or eighteen tons, and if it had also included several plots to show the effect of different qualities of manure, it is easy to see that the light thus poured upon the question would have been nearly equal to a demonstration.

Instead of this, the question of manure was here tested, as to its actual value, with only a single factor of 14 tons per acre, (annually increased by accumulation till the surplus nitrogen in the soil was probably over 2,000 pounds) without any appreciable increase of crop, and yet we are told that this is an exhaustive investigation, final and conclusive as to the real value of barn yard dung, and that in a soil yielding 23 bushels per acre without manure nothing less than 14 tons of animal dung will give an increase of barley equal to twenty-five bushels per acre.

THE FORMULAS EXAMINED.

Having now fully considered, and fairly met the various points thus far made in the defense of this theory, it only remains to consider briefly the essential facts and figures on which the system rests, and from which the formulas are constructed.

The following brief extracts from one of the Professor's lectures will sufficiently indicate the chemical foundation on which the theory rests:

"The elements which form all our agricultural plants are silica, lime, potash, magnesia, soda, phosphoric acid, sulphuric acid, and chlorine, found in the ash; and carbon, oxygen, hydrogen, and nitrogen, composing the aerial portion.

"Any element found in a plant, in its normal condition, however small the quantity, is a necessary constituent of that plant, and all elements not needed by the law of its composition are rejected.

"With rare exceptions the ash constituents are found in all soils, either free, or in some of their many combinations; and the organic elements always surround the plant both in the soil and in the air.

"Whatever aid the farmer may render the forces of nature in preparing food from the crude elements of the soil, the plants will consume the material faster than these forces can supply it. If, therefore, he would maintain the fertility of the soil, he must supply this deficiency by the application either of bulky material which can produce plant-food faster than the soil, or of the elements themselves in an available condition."

"The question here arises, is it not necessary to apply all the elements of nutrition, as they are all essential to the proper growth of the plant? It has been proved that of the four organic elements entering into the structure of crops, only nitrogen will ever need to be applied to the plant, for the others exist in a free and obtainable condition throughout all nature. It is likewise true that, with rare exceptions, the soil will manufacture with sufficient rapidity for all the needs of the crop, all the inorganic elements, with the exception of potash and phosphoric acid. Therefore, as an almost absolute rule, the three elements—nitrogen, potash and phosphoric acid—are the only ones which need to be supplied."

"It must be distinctly understood that only three elements of nutrition need be supplied to plants; not because they are indifferent to the presence of the others, but that nature can be depended on to supply them in abundance."

From these data the Professor has devised a method for applying the elements of plant-food to the various crops of the farm, so arranged that each crop has a formula adapted to its own requirements.

Let us now examine the principles on which the formulas are arranged, and see whether they can be relied on, as being at once, both sound in theory, and safe in practice. One thing at least is clear. If the elements of plant-food are here rightly discriminated, and if the theory is unmistakably sound, it is certainly important, and ought to be generally understood, and widely proclaimed. But are we quite sure that the principle of selecting and excluding chemical elements, as applied in these formulas, is really correct? Are we very certain that

"ONLY THREE ELEMENTS NEED BE SUPPLIED TO PLANTS?"

and are all the other constituents actually found in the soil at the time required, and IN THE RIGHT CONDITION?

In further examining and answering these inquiries, the following *formulas*, as published in the report of Amherst College, will perhaps be convenient for reference, and help to make the subject more clear.

POTATOES.

To produce one hundred bushels of potatoes per acre, and their natural proportion of tops more than the natural product of the land, and for other quantities in like proportion, use

Nitrogen	21 pounds.
Potash	34 "
Phosphoric acid	11 "
Total	66 pounds.

In the form of

Sulph. Ammon,	24	per cent.	dry salt	105 pounds.
" Potash	35	"	"	225 "
Superphos.	13	"	sol. acid	85 "
Total				415 pounds.

RED CLOVER.

To produce one ton of clover per acre more than the natural yield of the soil, use

Nitrogen	43 pounds.
Potash	40 "
Phosphoric acid	11 "
Total	94 pounds.

In the form of

Sulph Ammon.	24	per cent.	dry salt	215 pounds.
Mur. Potash,	80	"	"	80 "
Superphos.	13	"	sol. acid	85 "
Total				380 pounds.

INDIAN CORN.

To produce fifty bushels of the grain, and its natural propor

tion of stover to the acre more than the natural yield of the soil, and in like proportion for other quantities, use

Nitrogen	64 pounds.
Potash	77 "
Phos. Acid	31 "
Total	172 pounds.

In the form of

Sulph. Ammonia,	24	per cent.	of dry salt	320 pounds.
Mur. Potash	80	"	"	154 "
Superphosphate	13	"	sol. acid	248 "
Total				722 pounds.

WHEAT.

To produce twenty-five bushels of wheat, and the natural proportion of straw per acre more than the natural yield of the land, and in like proportion for other quantities, use

Nitrogen	41 pounds.
Potash	24 "
Phos. Acid	20 "
Total	85 pounds.

In the form of

Sulph. Ammonia.	24	per cent.	of dry salt	205 pounds.
Mur. Potash,	80	"	"	48 "
Superphos.	13	"	sol. acid	160 "
Total				413 pounds.

TURNIPS.

To produce one hundred bushels of turnips and their tops more than the natural yield of a given area of land, and in like proportion for other quantities, use

Nitrogen	11 pounds.
Potash	18 "
Phos. Acid	8 "
Total	37 pounds.

In the form of

Sulph. Ammon.	24 per cent.	dry salt	55	pounds.
" Potash	35 "	"	118	"
Superphos.	13 "	sol. acid	63	"
Total			236	pounds.

It will here be seen that the formulas of this theory are entirely made up from a small part only of the elements of plant food; and what is perhaps equally remarkable, the same three material are called for in every case whatever the intended crop may be. If, for example, a farmer whose land will produce fifty bushels of corn per acre without manure, desires to bring the yield up to one hundred bushels, he has only to consult the *corn formula* which tells him to add, in some available form, sixty-four pounds of nitrogen, seventy-seven pounds of potash, and thirty-one pounds of phosphoric acid.

Another man has perhaps a clover field with a normal yield of only one ton per acre, but thinks he ought to get at least three tons; and finds on inquiry, that, by this theory, in order to get two additional tons, it is only necessary to apply eighty-six pounds of nitrogen, eighty pounds of potash, and twenty-two pounds of phosphoric acid. He finds also that in each formula soluble forms of the elements are clearly specified, and the exact number of pounds for each is prescribed.

Though the *proportion* of the materials used in this system is varied for different crops, it is not varied to meet differences of soil; and it is also important to observe that the elements themselves do not vary in any case, but remain alway the same whatsever the crop and whatever the character of the soil.

It is true there are nine or ten other elements of plant growth which are, in all cases, equally indispensable to crops; but these, we are assured, "the soil will, with rare ex eptions, manufacture sufficiently, for all the needs of the crop;" and as the possible exceptions alluded to are so rare as not to be recognized in the formulas, it is clear they are considered of no account. Hence we find that in every section of the country, and under every

variety of conditions, wherever the banner of the formulas is unfurled, the same three inevitable elements re-appear, and are commended to the *exclusive* attention of the farmer, who is expected to go on ringing the changes on nitrogen, potash and phosphoric acid, while the soil itself takes care of the lime, soda, magnesia and the rest.

Now do the advocates of this system really believe that all the constituents of crops that are excluded from these formulas, are everywhere and always so munificently furnished by nature, and in a condition so completely available that the farmer can safely dismiss them from his programme? If this is so,

HOW HAS THE FACT BEEN ASCERTAINED?

and on what ground is it so positively assumed?

To this pertinent inquiry there does not appear to be as yet any sufficient or satisfactory reply. To say that "only three elements need be supplied to plants, because nature can be depended on to supply the others in abundance," and to tell us that this fact "must be distinctly understood," does not by any means meet the case. A statement often repeated, with varied phraseology does not amount to an argument. In the present case it merely takes for granted one of the most vital points in the theory; a point which has never been proved, and never can be, simply because the facts of experience are against it, as I now proceed to show.

The principle involved in the discussion of this point is very simple, and may be stated in a single sentence. Whenever any one or more of the plant elements omitted from these formulas is applied by the farmer to his land, and gives an increase of yield, this fact is a proof that the soil was deficient in that element, and hence that nature can *not* be safely relied on. It matters not, whether the material he has added to the soil produces its increase directly, or indirectly. In either case the augmented production has resulted from the presence and influence of the ingredient added by the farmer and if the material had been supplied by nature as promised in the theory, he would have received the

benefit without incurring the cost. Again it matters not if another farmer in the next field, should apply either the same or a different element without getting an increase of yield; for the two cases though apparently similar, are in reality very different In the latter case, the failure of increase does not necessarily prove that the soil was duly supplied with the element, since there are numerous other causes that would account for the lack of increase. While in the other case, the increase of crop can only be explained by the fact that the farmer has added something that the soil needed, and which nature had not sufficiently supplied.

But this is not all. The cases here compared are not yet exhausted, and the logical result is still stronger than it appears. Supposing the last point to be entirely waived, and conceding, for the sake of the argument, that the second farmer has made out his case in favor of nature, even then, the two cases, when taken together, would clearly refute the claim of the theory, which is, that "nature can be depended on to supply the other elements in abundance." Hence every time the farmer increases his yield by applying any element except nitrogen, potash and phosphoric acid, he virtually refutes the theory here examined.

On the whole, there is but one way, so far as I can see, by which this claim of the professor can be shown to be valid. If he has already secured a standing contract with the laws of nature in favor of this system, and especially specifying that the full amount required of every chemical element outside of his theory shall be in all cases forthcoming, at the right time, and in the right proportion and condition, then the theory is all right, so far as this point is concerned.

EXPERIENCE OF PRACTICAL FARMERS.

Let us now briefly glance at a few facts illustrating this subject, and tending to show how easily, and how often the farmer can, and does apply to his land some one or more of these rejected elements, because he does not think it safe to assume as a certainty that the soil will "manufacture" them in time for his crop; and

tending also to show that in most of these cases the result proves that the farmer is right and that he makes a sure gain by providing for the uncertainty of spontaneous fertility too often expected, and too seldom realized.

It is the practice of nearly all intelligent farmers to apply to their land at intervals a dressing of salt, lime, or plaster, and occasionally of lime and salt combined. When these applications are made with judgment and discrimination, they are very often successful, bringing an increase of yield, and sometimes a maximum crop. These materials taken together, contain five chemical elements of crops, neither of which is included among the three special ingredients of the formulas. They are also generally accessible, and rarely expensive. But according to the doctrine we are considering, the farmer who uses them unwisely incurs a needless expense, as they belong to a class of chemicals that nature supplies not only invariably, but "in abundance." Still it appears that farmers are so incredulous on this point that they *do* use these elements and thereby secure an increase of yield. It would be easy to fill a volume in enumerating such cases, but it is clearly not necessary. Now in every instance when these applications are made with a profitable result, they refute the theory of Professor Stockbridge, for they prove that the soil has been found deficient, notwithstanding the bounty of nature.

The same reasoning is also applicable to other chemical elements, as soda, magnesia &c., which though less abundant and more expensive, are sometimes used by practical farmers with decided increase of yield.

Prof. J. F. W. Johnston has cited some experiments made at his own suggestion by Mr. Fleming, and tending to throw light on this subject. A mixture of sulphate of soda with the nitrate in equal weights was applied to potatoes at the rate of one and one half hundred weight per acre, and the product was thirty tons. Neither of them separately produced over sixteen tons. This shows not only that the soil was deficient in sulphate of soda, but also that soda (both sulphate and nitrate) will in some

soils greatly increase the potato crop; and still further it shows the advantage of blending fertilizers, which often, as in this case, increases, and sometimes doubles the value of each.

In another experiment sulphate of magnesia, when added to the soil in connection with nitrate of soda, increased the yield from sixteen to twenty-two and a half tons, per acre. On another occasion Prof. Johnston, having noticed that the ash of grain is rich in phosphoric acid and magnesia, suggested a mixture of sulphate of magnesia, phosphate of soda and sulphate of ammonia, which was tried with marked success on wheat and corn. In the trial made on the corn crop, it tripled the weight of the stover, and increased the product of the grain six-fold. As this result is better than either of these chemicals produces separately, it shows that each of them was, in this case, needed, and that the soil was therefore to that extent deficient.

In another case Mr. Girwood found that an application of sulphate of soda to his bean crop gave an increase at the rate of sixteen bushels per acre.

EXPERIMENTS OF LAWES AND GILBERT.

In these very careful experiments running through a series of years, the manure question, as Prof. Stockbridge assures us, has been elaborately discussed. Let me then invite his attention to the testimony of some of these experiments which clearly show an increase of yield by adding to the soil a variety of chemicals omitted from the programme of the Professor, thus proving that formulas that teach farmers entirely to disregard such chemicals are defective and misleading.

Taking the average of the wheat experiments for twenty years we find that the increase from nitrogen, in the form of ammonia, is about nine bushels per acre ; and from nitrate of soda rather more. The increase from superphosphate alone, during the same period, averaged only two and one half bushels per acre, and from mixed mineral manures (potash, soda, and magnesia,) still less. Up to this point then these trials simply indicate that

the greatest need of that soil is nitrogen. But while this inference is sound in regard to nitrogen, yet when other plots are examined, in which various materials are combined, the experiment gives more variety of results, and teaches lessons no less valuable.

When the superphosphate, which alone gave only two and a half bushels of increase per acre, is added to the ammonia with its increase of nine bushels, the joint result is a yield of twenty-eight bushels, showing a gain of thirteen bushels over the normal yield. Again, when to this joint result of two fertilizers is superadded the combined effect of the other three, which had previously given even less gain than the superphosphate, the total yield of the five elements working together rises to a product of thirty-five bushels ranging from that figure up to forty bushels, and showing a gain of twenty to twenty-five bushels.

But what is perhaps still more important, and more to the purpose, it appears that when either of the three blended elements is added alone to the joint result of the superphosphate and ammonia, the total gain is still only one bushel less than when all are added together. That is to say, when to four hundred pounds of ammonia salts and three hundred and ninety-two pounds of superphosphate, are added either sulphate of potash, two hundred pounds; sulphate of soda, three hundred and sixty-six pounds; or sulphate of magnesia, two hundred and eighty pounds, the result is a yield ranging from thirty-four to thirty-nine bushels per acre, which is a gain of from nineteen to twenty-four bushels over the normal yield.

Now it is quite immaterial whether the influence of the soda, or the magnesia is direct or indirect in contributing to this result. It is enough to know that after the yield has reached its best possibility from the ammonia alone, and from the ammonia and superphosphate combined, there is a still larger result in reserve which is developed in the soil by the presence of either potash, soda or magnesia.

Nor is it material to the present purpose to show whether the increase clearly due in this case to the soda or magnesia is a true measure of their agricultural value. In some cases they would probably show less results, in others doubtless larger, as proved by some of the cases already cited. But is it not evident from these and other trials, that their value to the farmer, in view of actual results and possibilities clearly forshadowed, is too important to be entirely dismissed from his attention, or left to the chances of finding them in the soil when required.

The remarkable results produced by alkaline elements in connection with ammonia, as shown above, are further confirmed by the observations of Prof. Silliman, who visited the farm of Mr. Lawes, and examined his methods for publication in the New York *World*. In his report Prof. Silliman gives an account also of the

TREATMENT OF PERMANENT GRASS LAND BY MR. LAWES,

and of the amazing results obtained from silicate of soda in connection with other chemicals. Nearly all his facts and figures in relation to the hay crop point in the same direction as the wheat and barley experiments, and show that the greatest benefit from fertilizers is obtained when they are judiciously combined. The following passage cited from his report will interest farmers and will shed further light on several points relating to the topic now in hand.

"Those curious in such matters will wish to know what the exact treatment in the case was, and the facts are of sufficient interest to merit the attention of any thoughtful reader. The treatment was exclusively by mineral manures, without a particle of any kind of vegetable or carbonaceous substance whatever.

For example, in this particular case the annual quantities per acre employed were as follows, viz.:

	Pounds.
Sulphate of potassa	300
Sulphate of soda	100
Sulphate of magnesia	100
Superphosphate of lime 3½ cwt	392
Ammonia Salts, equal parts sulphate and muriate of ammonia	800
Total per acre mineral manure	1,692
To this quantity was added on another equal plot silicate of soda	400
Total	2,092

"The silicate of soda was commenced only in 1862, or thirteen years after the series of experiments were entered on. Its effects are most marked, for while the average for the first twenty years of hay cut was about sixty-one hundred weight, it rose for the twenty-second season (1877) to the enormous aggregate of one hundred and ten hundred weight!

"The land continuously fertilized with mineral manures of the above composition gave five and one-half tons of hay per acre and the adjacent unmanured gave two and one-fifth tons. It will be seen that the only source of nitrogen added by the treatment was from the salts of ammonia, while the carbon was evidently obtained by the plants from the carbonic acid of the atmosphere, since not a particle of carbonaceous food was supplied and the land had become practically exhausted of carbon. The chemical composition of the soil in this, as in every case, for each six inches in depth to a total depth of fifty-four inches, was carefully determined, and also the dry heath ash, nitrogen, woody fibre, fatty matter and composition of ash of the crop, and the percentage by weight of each species of grass and other plants in the mixed herbage accurately determined.

"Nitrogen, the most essential element of fertility, perhaps, for both cereals and grasses, is supplied most readily by the use of ammoniacal salts, but its highest effects are not attainable by the use of such salts alone, since the effect of such nitrogenous

fertilizers is much enhanced by the use of silicate of soda; and ammoniacal salts alone do not effect the same results which are attained when they are used in connection with certain alkaline salts, whether sulphates or nitrates. The same or a larger amount of nitrogen in the form of nitrate of soda or potassa fails signally to promote, on grass land, the production attained by the use of the sulphates of the same alkaline bases when ammoniacal salts are used as the source of the nitrogen."

THE WEAK LINK IN THE CHAIN.

But there is another view of the subject, which, though too often overlooked, is very important. At the Connecticut Farmers' Meeting the Professor very truly remarked that "the lack of any single element of plant nutrition, or even of the right proportion of any element, is fatal to the plant." Yet in prescribing the plant food for a corn crop of fifty bushels, or a clover crop of one ton, while giving the exact figures of the formula for each of the three elements it contains, he seems to lose sight of the fact, that if any one of the other nine elements should happen to be deficient in the soil, and thus cause either a diminished yield, or a total failure, then each element in the formula would be limited and controlled by that fact and the possibilities of the theory would be at once cut short, if not destroyed.

Let us take an illustration. The soda, magnesia and lime required for fifty bushels of corn amount, together, to about eighty pounds, and for a ton of clover, to about fifty pounds. Now if we suppose the total amount of these elements contained in the corn field to reach even several thousand pounds per acre, and in the clover field as much more, yet if the amount of them, actually available as nutriment, should be, in the corn field, only fifty or sixty pounds, or in the clover field only twenty-five or thirty pounds, either of which is possible, what would be the result? Not only would the nitrogen, potash, and phosphoric acid be deprived of their value, but the crop itself would be a failure.

To make the case still stronger, if any single element, instead of all three, should fall short of the amount required as nutriment for the crop; if for example, the lime, or sulphuric acid should be sufficient only for twenty bushels of corn, or half a ton of clover then a thousand pounds of nitrogen, or any other constituent would neither bring up the yield to the prescribed amount, nor make any impression on the result. No chain is stronger than the weakest link, and if a slight deficiency of supply should make magnesia or soda a weak link in the chain, then the phosphoric acid, and all the other elements are brought to the same level, and that is the limit of yield for the crop.

THIS PRINCIPLE OF PLANT-FEEDING,

though obscure in its operation, and not always easy to detect, is yet immensely important. The fact that any single element of nutrition which by some chance is either not duly supplied, or too slowly developed in the soil, is thus able, by its mere deficiency, to hold a veto power over all the other elements and neutralize their effect, however abundant they may be, or however costly to the farmer, the mere fact, for example, that a few pounds of soda that happen to be absent, can outweigh ample tons of potash that are promptly on hand at the time required, such facts, I repeat, cannot be safely overlooked.

But the obscurity that hangs over chemical processes in the soil makes it often difficult and sometimes impossible to meet such cases with timely remedies. This is a more serious and prevalent evil than most of us seem to realize; and it is unquestionably one source of the doubt, and discouragement so frequently encounteredby intelligent practical men. It produces many unexpected results and seeming contradictions, often perplexing progressive farmers, and bringing the experience of the wisest men into collision, and more than all, it imparts to careful and elaborate experiments strange incongruities that hide their true meaning and value, and thus weakens the general confidence even in the soundest teachings of chemical science.

THE ELEMENTS OF PLANT-FOOD MUST BE ADAPTED TO THE SOIL.

Having now clearly proved that this theory has not been successful in adapting its formulas to the needs of the *crop*, which it distinctly claims to do, let me next proceed to show that it is still more unfortunate in not adapting them, nor even *attempting* to adapt them, to the needs of the *soil*.

It is well known that soils differ so often, and so widely, in their constituent elements that a fertilizer adapted to one is not necessarily suited to another, and that if wrongly applied in a given case it may entail a loss instead of a gain. Yet these formulas make no distinction between rich and poor land, nor do they even recognize the fact that some soils have already, in sufficient amount, one or more of the elements prescribed by the theory.

A plan more inconsistent than this, or more opposed to true economy, can hardly be conceived. It involves the necessity of applying more plant-food than is needed, and the possibility of using, in some cases, three elements (two of which are not needed), in order to make sure of one.

The farmer who undertakes to raise a wheat crop in accordance with this doctrine, is required to apply three chemical fertilizers, each in a definite and fixed amount, without stopping to inquire how many of them, or what part of each, his land already contains. It is deemed enough for him to know that 25 bushels of wheat require 41 pounds of nitrogen, 24 pounds of potash, and 20 pounds of phosphoric acid; and that if he puts these several amounts into his land, the 25 bushels will be forthcoming at harvest. Just as if the yield per acre were the only thing to make sure of, and the cost of production were of no consequence.

To show how this theory sometimes works in practice, in consequence of ignoring the condition of the soil, let us glance at

A FEW INSTRUCTIVE EXPERIMENTS.

The following statement of Professor Geo. Cook, of New Brunswick, giving the results of some experiments with corn, speaks for itself in a convincing manner:

"These results showed a yield of 85 bushels of corn and 2¾ tons of stalks to the acre, without any fertilizer, valued at $76.47.

An application of 100 pounds Muriate of Potash, costing $2.75 per acre, gave an increased value of $13.55.

An additional application of 300 pounds Sulphate of Ammonia, and 300 pounds Superphosphate of Lime, costing $16.65 per acre, gave an increased value of $12.68.

An application of 400 pounds Sulphate of Ammonia and 300 pounds Superphosphate of Lime with the Potash, costing $26.65, gave an increased value of $13.67.

An application of 200 pounds Sulphate of Ammonia and 500 pounds Superphosphate of Lime with the Potash, costing $19.25, gave an increased value of $17.31."

Four applications were here made for testing separately and together the three elements contained in the corn formula.

One of the four, in which potash was used alone, showed a profit of $10.80 per acre.

In the third application, which included all three of the elements, the cost was very nearly twice the amount of the increase and the net loss about $13 per acre. This makes a difference in the cash results of the two cases equal to A LOSS OF OVER $23 PER ACRE, by using the three elements together instead of the potash alone. Yet the theory in question insists on using ALL THE ELEMENTS OF THE FORMULA IN ALL CASES.

Again, we have this same instructive lesson confirmed (together with some other points of interest) in the following experiment with potatoes, reported by Cornell University to the *Elmira Husbandman*. The variety of potato planted was the Early Rose. The seed consisted of medium-sized whole potatoes cut into halves, a single piece being dropped every eighteen inches and covered about five inches deep:

		Fertilizer applied.	Yield of large.	Yield of small.	Total yield.
Plot No.	1.	Farm yard manure (on bottom)..	120 lbs.	43	163
"	2.	Farm yard manure (on top).....	148 "	59	207
"	3.	Ground bone.....	196 "	16	212
"	4.	Superphosphate (Lister Bros.....	163 "	21	184
"	5.	Superphosphate (Syracuse).....	152 "	19	171
"	6.	Pacific guano.....	118 "	32	140
"	7.	Peruvian guano.....	142 "	16	158
"	8.	Hen manure.....	132 "	13	145
"	9.	Stockbridge fertilizer.....	105 "	30	135
"	10.	Nothing.....	102 "	37	139

In this experiment the potato formula, containing the same three elements as above, was tested in connection with several other fertilizers. It will be seen that, in this case, as before, the Stockbridge formula, when used entire (in No. 9) shows a much less yield than is given by a part of its elements applied separately in No. 3. And what is quite remarkable, on comparing the ten plots together, we find that the total formula gives the lowest yield of all, while a mere fraction of it in No. 3 gives the largest of all. It will also be seen that these three infallible elements, which, I believe, claim to be called a "complete manure," are here surpassed, in the total yield, *by every fertilizer in the experiment.* In the previous experiment it was the potash element that asserted itself; in this instance it is the phosphatic element.

Again, in a wheat experiment by J. I. Carter, of West Grove, Pa., the point above illustrated is still further emphasised. The Wheat Formula is tested in comparison with bone superphosphate (which contains some nitrogen), rock superphosphate (without nitrogen), and a fourth plot without manure. The following is the result:

1.	Wheat Formula..Grain.....	26 bush.	Straw.....	2,080 lbs.
2.	Bone Superph....Grain.....	33 "	Straw.....	2,326 "
3.	Rock Superph...Grain.....	35 "	Straw.....	2,650 "
4.	No Fertilizer....Grain.....	24 "	Straw.....	2,280 "

In comparing these products we find that the rock superphosphate (in No. 3), containing but one element of the formula, gives the largest product, both of grain and straw; showing an increase over the unmanured plot (No. 4) equal to 11 bushels of grain, and 370 pounds of straw per acre; while the entire formula (in No. 1) gives an increase of only 2 bushels of grain, and on the straw a positive loss of 200 pounds.

Thus it appears that the total loss incurred by applying the three elements of the theory, when only one is needed, is a serious matter, and is not limited by any means to the mere difference of yield, but includes also the loss on the fertilizer, as well as on the crop, and amounts altogether to 9 bushels of wheat and 570 pounds of straw per acre, plus the nitrogen and potash applied without effect; and as these two fertilizers would cost (in the forms specified by the theory) about $10, it makes the money value of the entire loss nearly $20 per acre.

Many other cases might be cited pointing in the same direction as those here given, but further illustration is scarcely required.

Now, for results so startling as these, it is not sufficient merely to say in their defense that such cases are of rare occurrence, or that they are more than compensated by examples of success. Without denying the possible cases of comparative success, or disparaging the value of any results that are fairly proved, I yet submit that such decisive and fatal results as those above quoted could not occur in a sound system, and ought never to be possible in a theory emanating from scientific sources, and supposed to be indorsed by the imposing authority of an agricultural college.

The explanation usually given for ignoring the condition of the soil in carrying out the details of this theory seems to be substantially as follows: The chemist knows accurately what elements are contained in crops; therefore it is safe to adapt our methods to the requirements of the crop. But the chemist does

not sufficiently understand the contents of the soil, nor the condition of the plant-food contained in it; therefore it is not safe, nor even possible to prescribe the chemical elements required by the soil. Now, it is easy to see that

THIS DEFENCE IS MORE PLAUSIBLE THAN SOUND.

But the answer is plain and simple. The farmer *must* adapt his fertilizers to the soil, or else cease to apply them; for there is no other way to make chemical farming pay. If he does not fully understand the soil (which is true enough) he must be guided by the light he has and get more as soon as possible. If the chemist can not enlighten him, he must look to his own experience, judgment and skill. For just so far as he is in the dark on this point, to that extent his fertilizing is a game of chance. It is very certain that the more ignorant we are of the contents of the soil, the more risk we run in applying chemical elements that are certainly expensive, and some of them, from our lack of knowledge, either entirely useless, or positively hurtful.

If, then, it is true, as claimed by the chemist, that we can not yet understand the condition of the soil in regard to the plant-food contained in it, and therefore can not make sure of the constituents required, except by some plan that includes both those that are needed, and those that are not, and if consequently there is no alternative for farmers, but to accept this theory as it stands, with all the risk of purchasing and applying what is already in the soil, then I have only to say that the time for the chemist (on this question) has not yet arrived, and until he has something better to offer, he may safely stand aside, and make room for the practical farmer.

YET EVEN AMONG FARMERS

there is, of course, a wide difference. There are possibly a few who are mere laggards and drones that neither gather wisdom from the past nor have plans for the future. They are simply

exceptions to their class, and care but little for methods. But it is certain that a majority of American farmers are men of a different type. They are men of intelligence, who derive from the experience and observation of every year some additional knowledge of their soil, its condition and its wants. There are also others still more progressive, who carefully examine and record their experience, and compare results with their neighbors and with their clubs. They are continually gathering new facts from their soil, and new ideas from the journals they read.

Such men, while steadily progressing and improving, are not insensible that they have still much to learn, and are glad to increase their own limited knowledge from all the accessible resources of science, and from all its reliable conclusions. Without claiming to be wiser than others they often get large and profitable crops without the aid of formulas, and occasionally a maximum yield and a minimum cost, as the result of their own investigations and successful experiments. Possibly some of them may even have *experiment on the brain*, and may solve this problem sooner than we expect.

Now, farmers of this class do not pretend to be superior to the teachings of chemistry, but, on the contrary, are anxiously waiting for its higher illumination, and hail with pleasure every new acquisition from scientific men.

Yet if the only method, or the best method of chemical farming to be obtained from this source is found to omit nine or ten elements of plant-food on the fallacious theory that the soil will always furnish them in the right condition, in the full amount, and at the right time, and if it also involves the necessity of supplying too much or too many of the elements of nutrition, even to the extent of possible injury, then all that remains for the tillers of the soil is to fall back on their own resources, for they are bent on finding, and certainly will find, either with the chemist, or without him, some safer and surer method of supplying a deficient soil and feeding a hungry crop, than any yet revealed.

FEEDING HABITS OF DIFFERENT CROPS.

The ability of plants to appropriate the nutritive materials in the soil has a direct bearing on their vigorous growth. This is a point on which they often widely differ, and is consequently a matter of much interest to the farmer. The more easily and thoroughly they assimilate the plant-food in the soil, or in the air, the more rapidly they grow and thrive. But it is an unfortunate peculiarity of this system that it fails to recognize any distinction on this point. It is now quite generally understood that leguminous plants, and a few others, have an exceptional affinity for nitrogen, which, of course, gives to these formulas a a special interest for all such cases. This peculiarity of nitrogen is more or less developed in a considerable variety of crops, and is therefore a fact of immense importance. And yet, in the published formulas of this theory the distinction is not recognized, although nitrogen is the leading factor, and far the most costly.

It is the opinion of Mr. Lawes, as the result of many trials through many years, that it is not expedient to apply artificial manures to leguminous plants; and in regard to nitrogen, on which he has bestowed especial attention, his opinion in this case is undoubtedly sound, but in regard to other artificial manures it would be very safe to make some reservation in favor of leguminous plants in certain cases, as, for example, in the case of soda applied to beans, (See page 43.) But this point may be more properly discussed hereafter.

In some remarks made by Professor Stockbridge two years since at the State Board of Connecticut, he clearly admits that there is a risk and a loss of nitrogen in some of the formulas, and also a loss of potash in some of them, and yet it will be seen in the following passage from his address that he does not hesitate to confirm the formulas as originally given:

"I agree that some plants can gather nitrogen from natural sources, and we need not apply it. All probably gather some, and some classes of plants more than others."

Again he says:

"There is no mistake about the fact that clover, beans, and the legumes generally, are great gatherers of nitrogen. It is probable that wheat gathers some. And yet, in our present condition, from our present standpoint, I do not dare to risk it. I do not dare to send out a r and say it will do so-and-so, unless I put all the things in. I agree with Prof. Atwater that there is a little loss here. I have put nitrogen for some crops that I know I need not have paid for. There is a little loss of potash, for I have put in potash for some crops that I need not have paid for. That is exactly so. But here is the point. I find it would be impossible for practical farmers, with their ordidary system of farming, to ascertain the fact whether they need potash or not. Prof. Atwater might find it out, perhaps I might find it out, but taking farmers generally, I think there would be a failure. I think I know that with nitrogen, potash and phosphoric acid, mixed in a certain way, farmers will get their crops; I do not know but they would get their crops if I left out a little potash; I do not know but they would if I left out some other things, but I do not dare to risk it. Give me time enough, and perhaps I will run these little threads out, and find out how much nitrogen I should leave out of the corn-fertilizer, or out of the wheat-fertilizer, or out of the clover-fertilizer, but you must give me time. Until I learn that, I say, "I know nitrogen, potash and phosphoric acid will do such-and-such things." I do not know but I might take out a little. Until I do know, I do not dare to change my formula as a rule of general application."

Is it not amazing that after these admissions the Professor still keeps these formulas unchanged!

How can he help seeing that the losses, the doubts and the perilous uncertainty here conceded by him are virtually but little less than a surrender of the theory for a large class of crops.

When he says: "I think I know that with nitrogen, potash and phosphoric acid, mixed in a certain way, farmers will get their crops; I do not know but they would get them if I left out a little potash, * * * or some other thing, but I dare not risk it." Is it not pertinent to remind him that according to his previous statement he has already taken a serious risk by put-

ting in nitrogen and potash at a loss? Does he not realize that the formulas for leguminious crops (to say nothing of the others) are already so loaded down with needless cost that nothing less than total reconstruction can make them safe?

Exhaustion of Soil.

The claim has been made by the advocates of the Stockbridge Formulas that they do not exhaust the soil; and, "that all experiments on this point have shown this conclusion to be practically correct." It is also claimed that "the experiments of Lawes and Gilbert during thirty years on the same land, conclusively show that their soil has yearly increased its store of fertility with the constant use of chemical manures."

Now, the statement as to what "all experiments have shown," it will be time enough to deal with, when such experiments are brought forward. For the present, it is sufficient to say, that no experiment has yet been applied to any staple crop under the Stockbridge Formulas that has been correctly made, duly attested and accurately reported, including all the facts and figures that belong to it.

It is therefore, of course, equally true that no *series* of experments has yet appeared, under those formulas, that are fairly competent to show that his theory does not tend to impoverish the soil. This assertion is made distinctly, and without qualification, and if any advocate of the system thinks differently, and will venture to bring forward such experiments, practical farmers will soon have an opportunity of judging whether I am right or wrong.

In regard to the experiments of Lawes and Gilbert, as above referred to, the answer is: First, That between those comprehensive and elaborate experiments, and the limited formulas of the American theory, there are but few points of resemblance, and those few are adverse to the formulas, as I have already shown.

These experiments of the illustrious English farmer, though of great interest, and highly instructive, are far from being perfect,

but the further examination of them on their general merits must be deferred for a future occasion and a more direct discussion.

Second, There is no occasion to deny or to question the fact above stated in regard to the soil of Rothamsted, and its increasing fertility under chemical manures. But it proves nothing to the purpose in the present case. No sensible man will deny the possibility of improving and maintaining the soil with chemical elements, by duly increasing the variety and quantity of them until the object is gained. It is merely a question of cost. The same results achieved in England can be produced here, at short notice, by any man who has the necessary capital and pluck. But

THE FACT SEEMS TO BE ENTIRELY OVERLOOKED

that Mr. Lawes applied in his wheat experiments, not only the three elements embraced in the American theory, but various others, including soda, and magnesia, and all of them in very much larger quantity. Instead of limiting himself to three elements with a total weight of ingredients amounting to 400 pounds, he used about twice the number of elements, and more than quadrupled the weight prescribed by the wheat formula of the Professor.

The total amount of chemicals used at Rothamsted ranged from about 1,400 pounds per acre to over 2,400 pounds, and it was only with the latter quantity that the largest yields were reached.

Is it, then, any wonder that Mr. Lawes obtained large products without impoverishing his land? Would it not rather be amazing if he had failed to do so? But these imposing results obtained at a fabulous cost will hardly mislead American farmers, for they well know that any man attempting the same thing here would soon find himself brought to grief, and buried financially beyond the hope of resurrection. Yet we are told that this sustained fertility ensured only by a profusion of chemicals that were measured by thousands of pounds per acre

proves that a formula limited to three elements, and to less than one-fourth the total amount, will in like manner insure munificent yields, and increasing fertility of soil.

It is certainly not difficult to perceive in this case

THE FALLACY OF THE REASONING.

It assumes that when three elements are applied to the soil, this restores all the plant-food taken out by the crop. Let us see if this is really true. When the Professor in his trial crop, already examined, claimed that 50 bushels of the yield were due to the fertilizers applied, he still had left 44 bushels due to the soil. That shows that he only returned a little over half the amount of the three elements, taken out by the crop. But this is not all. There were nine other elements also abstracted by the crop in larger or smaller amounts. Yet it won't do to say that these elements can all of them safely be left to the care of nature, for I have already shown by unmistakable facts that this is not so, and that some of the best authority agree in this conclusion.

How, then, does the case stand? Simply thus: The soil was impoverished, in regard to nine of its elements, to the extent of ninety-four bushels of grain, and the corresponding stover. It was also further impoverished, in regard to the other three elements, to the extent of 44 bushels with the stover. Still we are expected to believe that the soil in that case was not impaired, because in another case, it was maintained by an application of nearly a ton of plant-food covering five or six varieties of elements.

Nitrogen Not Recovered.

It is a question well worth examining, though seldom duly considered, what proportion of the fertilizers applied to the land actually reaches and enters into the plants for which it is intended. It is very evident that in nearly all cases some portion of each element applied fails to find its way into the crop. This arises from a variety of causes that need not here be discussed. The extent of this loss depends in part on the mode of treatment, but largely also on the condition of the material, the condition of the soil, the feeding habits of plants, &c.

Of course the amount of plant-food that thus fails to reach the crop is part of the expense of manuring, and therefore a factor in the cost of production. With some fertilizers the amount of loss from this case is small, and may be disregarded. But with others, and especially with nitrogen, the amount is quite a serious matter, and no careful farmer can afford to disregard it.

Mr. Lawes, in a letter to the *Scientific Farmer*, has stated that with the cereals, in his experience, nearly one-half the nitrogen is not recovered in the increase of crop. It also appears from a table quoted by Mr. Harris, and extending through many years, that the average proportion of nitrogen not recovered is over 60 per cent. If it shall be found on further investigation that even 30 or 40 per cent. of this costly element on a general average is lost to the crop, it is a matter too serious to be disregarded, and seems to require some change in the formulas. In fact it is evident that the whole question of nitrogen as it stands in this system might be reconsidered with advantage.

THE COST OF PRODUCTION

for crops raised under this system of chemical farming is after all the only true measure of the value of the system. To this question I have already briefly referred, but in view of its conceded importance, it demands further examination. I have referred also to the fact that we have as yet no practical trials of this theory made with such accuracy, clearness and fulness of detail as to warrant us in accepting them as a demonstration.

This is the more to be regretted, because it is well known that one such trial, if wisely planned, and faultless in its execution, would shed more light on the system, and be worth more as an argument, than a hundred trials defectively made, with essential conditions left out, and having consequently no logical value.

Every crop raised under a new theory is really an experiment, however imperfectly performed, and however regarded by the man who performs it. He is consequently working in the interest of a problem, and helping forward its final solution. It is a question of profit or loss, not for one crop or season

only, but for the rest of his life; and not for one man only, but for every tiller of the soil, and every consumer of bread. Each ray of light struck from the soil in these experiments creates a new value in husbandry, and is often a new factor in the cost of production. It belongs not to an individual, but to the whole community of farmers.

COST OF THE CHEMICAL ELEMENTS OF CROPS.

In order to determine the cost of producing crops, by this system, let us first examine the cost of the fertilizers. In the case of corn, according to the latest circular of Bowker & Co. (1878) the fertilizer is charged at the rate of $20 for 40 bushels of the grain, which is equal to 50 cents per bushel. For wheat the charge is at the rate of $15 for 25 bushels of the grain, which is equal to 60 cents per bushel. This makes the average cost of the materials in both cases equal to 2½ cents per pound.

In addition to this the farmer pays the freight charge, and the cost of hauling to the field, and applying to the crop, which would vary somewhat according to difference of locality, &c., and would range from 5 to 10 cents per bushel. With these additions the total cost of fertilizers for an increase of corn equal to 50 bushels per acre would be from 55 to 60 cents per bushel; and for an increase of wheat equal to 25 bushels per acre would be from 65 to 70 cents per bushel.

Yet these figures do not measure the entire cost of the extra bushels obtained. There are other factors also that enter into the calculation, and increase the cost.

But the final question to consider here, and in which the others are merged is this: How does the increase of yield produced by fertilizers effect the cost per bushel for the entire crop? Viewed in this connection the cost of chemical elements in its connection with staple crops, becomes widely interesting, and assumes an aspect of even national importance.

If we take the price of the materials in the corn-formula at the rate of 50 cents per bushel of grain (as appears in the circular of

Bowker & Co.*), and assume the expense for freight, hauling and applying the same, to average 7 cents per bushel, we then have for the total cost of the fertilizer when placed in contact with the crop, 57 cents for each bushel it is assumed to produce. It is immaterial whether the farmer orders the formula for 50 bushels or some other amount; the cost being at the same rate.

At this point arises another question. If the formula applied is adapted to a gain of 50 bushels, and the yield proves to be 65 bushels, does the amount paid for the formula cover the cost of plant-food for the entire crop? Certainly not. The other 15 bushels are due to the capacity of the soil. But the cost to the farmer is none the less certain, whether paid for in money, or in lost fertility. Whether the yield is 20 bushels, or 120, it makes no difference. If he is a correct business man, he charges to the crop the chemical elements for every bushel of yield.

Well, says the inquirer, conceding the charge to be correctly made for the whole crop, is the entire cost of plant-food then covered? There are several reasons why it is not. It is found, as a rule, with hardly a single exception, that a part of the nitrogen applied to crops is not returned in increase; and this is also true in some cases in regard to phosphoric acid.

What, then, is the proper amount of loss to charge for the partial failure of these elements to reach the crop? That is more than we can at present determine. But it is certain that such loss is one of the factors in the cost of production.

So far, then, says the interrogator, the case may be admitted, as to the fact of a loss: But if we suppose that a certain percentage on the cost of the fertilizer will represent this defiency, is there any other item of cost for plant elements to be charged to the crop? There is undoubtedly another loss under this theory that is not yet provided for. There are nine elements omitted

*"We guarantee to furnish the amount of plant-food required according to Professor Stockbridge's formulas to produce the *minimum quantity* of crop stated with each manure, and in the right form for each crop."—*Circular of* 1878.,

n the corn formula for $20, the minimum quantity stated is 40 bushels.

from the formulas, that are extracted from the soil by every crop, and for which no provision is made. Have we any means of knowing what this loss amounts to? We shall doubtless understand this subject much better as chemistry advances. At present we can not measure the extent of this exhaustion, though we know that in some cases the soil responds promptly and generously to an application of such elements as soda, magnesia, lime, &c., which proves two things: First, that the crop needs them; and, second, that the soil does not contain them in sufficient amount.

Let us now briefly refer to the other factors that belong to the cost of crops. Though the experience of farmers differs widely in regard to these, it will not be difficult to estimate them nearly enough for the present purpose.

The cost of labor and seed for an acre of corn has been estimated by J. I. Carter, of Pennsylvania, at about $12, and by Professor Sales, of Michigan, at very nearly the same figure, while some others in that section made the cost more, and further East it reaches a still higher figure among the best farmers. In a successful crop of nine acres Joseph Harris found the cost of these items to be $26. Dr. Sturtevant, on several estimates made at different times, and under different conditions, has found the cost to vary from less than $20 to nearly $30. On comparing a considerable number of cases, the average in New England and New York appears to be, among the best farmers, about $22 per acre.

For interest, taxes, &c., the usual estimate is $10 per acre, but it often exceeds that sum.

The amount of stalks for each bushel of grain is held to average, when well cured, from 90 to 100 pounds, and the value per ton is not less than $8.

There should also be added to these figures a small percentage on the cost of the fertilizers to represent the proportion that does not re-appear in the crop, and also a moderate estimate to

represent the exhaustion of soil from the elements not included in the formula. Let us put these figures for the present at the merely nominal rate of 5 per cent. each, on the cost of the fertilizers, making a total, for the two, of 10 per cent.

If we now tabulate these figures for a crop of 65 bushels per acre, under a formula for 50 bushels, and concede that the normal yield is only 15 bushels (which is not only uncertain, but improbable) we shall have the following result:

Cost of labor and seed	$22.00	per acre
" chemicals for 50 bushels, at 57 cents	28 50	"
" chemicals for 15 bushels, at 57 cents	8.55	"
Loss on nitrogen not returned 5 per cent.	1.85	"
" from exhaustion [not otherwise covered], 5 per ct.	1.85	"
Rent and taxes	10.00	
	72.75	
Cr. stover, 3¼ tons at $8	26.00	
	$46.75	

This makes the cost 72 cents per bushel.

If now, under this same formula, we assume the yield to be 75 bushels per acre, instead of 65 the cost would then be 66 cents per bushel.

Or if, without any change in the yield, we reduce the estimate by omitting the percentage of loss, and call the labor account $20, this would make the cost per bushel for the crop 63½ cents.

Now it is perfectly evident that no such cost as this for Indian corn can ever make it a paying crop. Every sensible man knows that it is produced every season and in every section of the country by countless practical farmers at less than half the above cost, nor is there any sufficient reasons why this great staple should not be grown at 25 cents per bushel, or less as a general rule, even in New England. There is a method by which this result may be reached and often surpassed by a majority of farmers; but the *key* to the method is only to be found in *a right system of experimental farming.*

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